Mini AERCam

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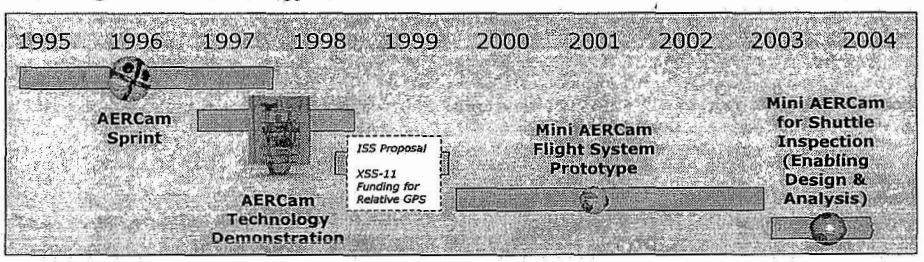
AERCam Background

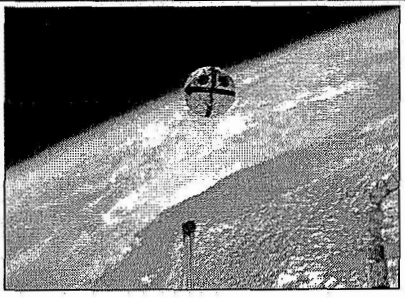
AERCam History

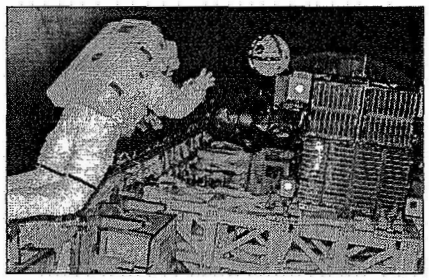
- AERCam is a nano-satellite class free-flying spacecraft with a full suite of avionics, propulsion, navigation, and communications
- Nearly 10 years of development at JSC
  - 3 major development programs, one ending in DTO of protoflight unit, other two ending in ground demonstrations with integrated hardware and software
  - Incremental increase in capability to reduce crew workload, provide better inspection capability
  - Two crew evaluations
  - Significant technology advancement



AERCam Sprint on STS-87

- Flight tested in December 1997
- Released during EVA by Winston Scott
- Remotely piloted by Steve Lindsey from the Orbiter aft cockpit
- Flown for over an hour around the Payload Bay
- Demonstrated capabilities included automatic attitude hold, piloted translational and rotational maneuvers

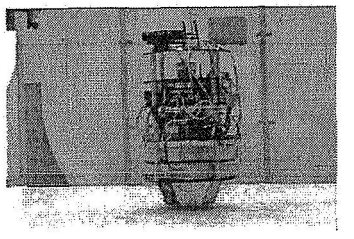




AERCam Technology Demonstration 1997-1998

Demonstrate advanced capabilities

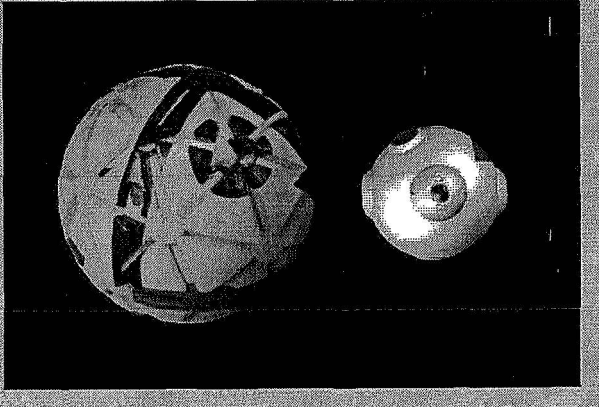
- Better processor than Sprint (Pentium 166 instead of 80C196KC)
- Indoor navigation system used a Litton LN-200 and pseudolite-based relative nav (largely based on Stanford University implementation)
- Collision detection using ring of infrared sensors
- Stereo pair of cameras, stereo tracking
- Automatic translation hold
- Wireless Ethernet for communications



Air-Bearing Table Demonstration in the JSC Building 9 Hi-Bay, 1998

Mini AERCam Flight System Prototype

Mini AERCam was initiated by JSC Engineering Directorate in early 2000: Goal to reduce size and increase capability



Mini AERCam Features:

- 2 orthogonal video cameras
- 1 high-resolution still camera
- Recharge/refuel
- Wireless Ethernet communications
- Relative GPS
- Automatic attitude hold
- Automatic translation hold
- Automatic point-to-point maneuvers

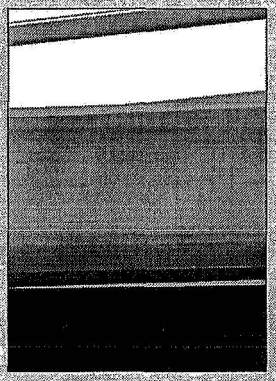
Weight decreased from 35 lb to 10 lb
Mini AERCam is 1/5 the volume of AERCam Sprint

Mini AERCam for Shuttle Inspection

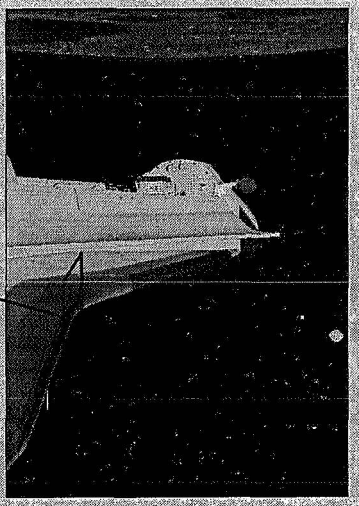
Provide Free Flying Shuttle Inspection Capability

Mini AERCam Features:

- Addition of inspection sensor to inspect for damage to TPS
- Components upgraded to flight
- Detailed Shuttle integration design
- Hangar with recharge and refuel



View from AERCam inspection camera (simulated)

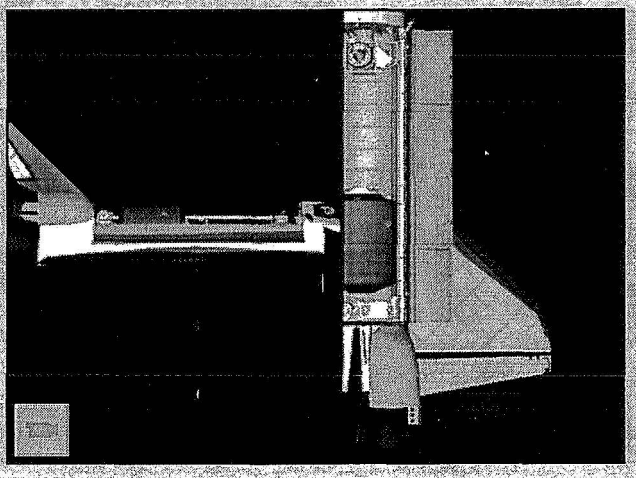


AERCam at 15-foot standoff (shown to scale)

Mini AERCam for Shuttle Inspection

Mini AERCam Wing Leading Edge RCC Scan

- Shown 60x faster than real-time
- Shown to scale (which is why Mini AERCam is a dot)
- Complete visual scan of RCC in four passes
- Actual time is about 30 minutes



Mini AERCam System Development

Mini AERCam System

- Three major elements of the Mini AERCam System

Free Flyer

- Viewing/Inspection
- Free Flight
- On-board Autonomy

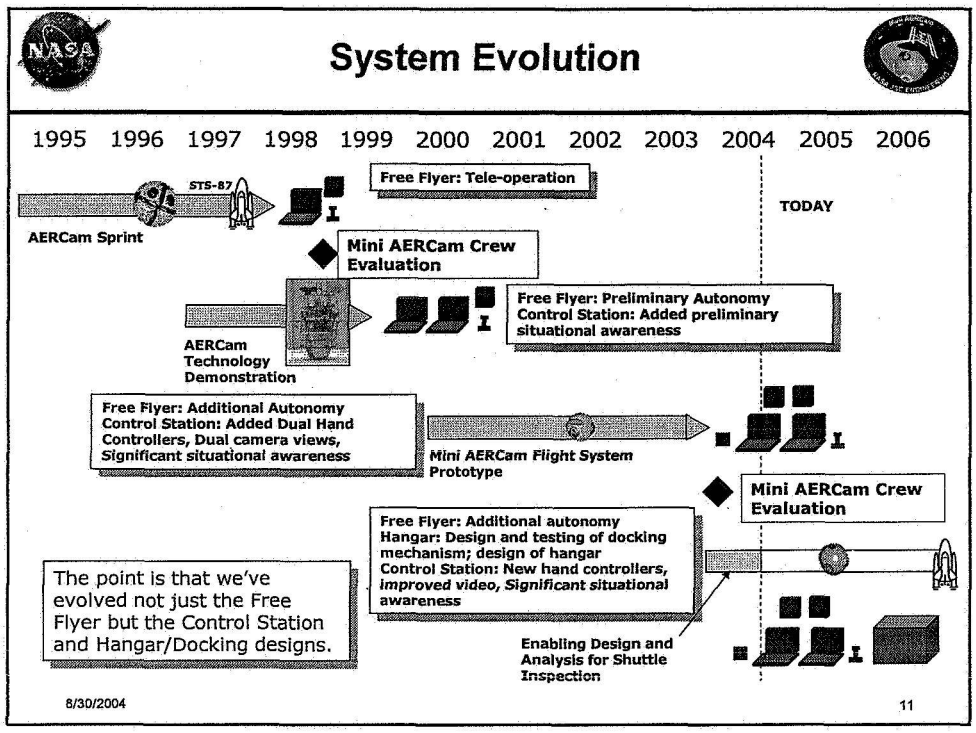
Control Station

- Crew monitoring
- Remote piloting
- Commanded Automatic Maneuvers

Hangar

- Deployment
- Docking
- Recharge

It is easy to only consider the Free Flyer portion, but all three system elements must be designed to work together, and to work with crew or ground and within the supporting infrastructure.


System Evolution
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
STS-87
AERCam Sprint
Free Flyer: Tele-operation
TODAY
Mini AERCam Crew Evaluation
AERCam Technology Demonstration
Free Flyer: Preliminary Autonomy Control Station: Added preliminary situational awareness
Free Flyer: Additional Autonomy Control Station: Added Dual Hand Controllers, Dual camera views, Significant situational awareness
Mini AERCam Flight System Prototype
Mini AERCam Crew Evaluation
Free Flyer: Additional autonomy Hangar: Design and testing of docking mechanism; design of hangar Control Station: New hand controllers, improved video, Significant situational awareness
The point is that we've evolved not just the Free Flyer but the Control Station and Hangar/Docking designs.
Enabling Design and Analysis for Shuttle Inspection
8/30/2004
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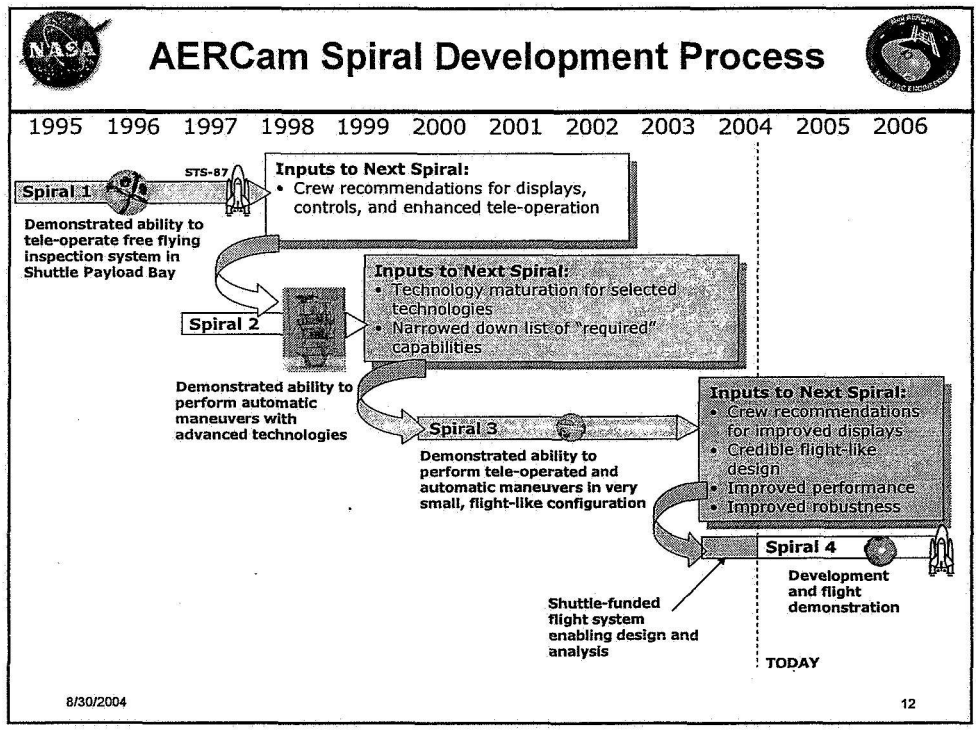
AERCam Spiral Development Process
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Spiral 1
STS-87
Demonstrated ability to tele-operate free flying inspection system in Shuttle Payload Bay
Inputs to Next Spiral:
• Crew recommendations for displays, controls, and enhanced tele-operation
Spiral 2
Inputs to Next Spiral:
• Technology maturation for selected technologies
• Narrowed down list of "required" capabilities
Demonstrated ability to perform automatic maneuvers with advanced technologies
Spiral 3
Demonstrated ability to perform tele-operated and automatic maneuvers in very small, flight-like configuration
Inputs to Next Spiral:
• Crew recommendations for improved displays
• Credible flight-like design
• Improved performance
• Improved robustness
Spiral 4
Development and flight demonstration
Shuttle-funded flight system enabling design and analysis
TODAY
8/30/2004
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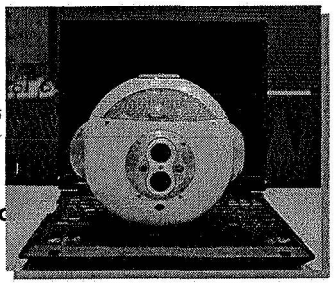
Mini AERCam Flight System Prototype

Better Than Sprint, and Smaller Too

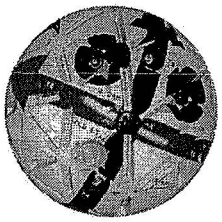
- **Mini AERCam is the successor to Sprint**
  - **The successful Sprint flight test yielded recommendations, including improvements for situational awareness**
  - **A follow-on crew evaluation yielded further recommendations for enhanced tele-operati**



- **The Mini AERCam Flight System Prototype was initiated in 2000**
  - **Engineering designed and built the smaller and more capable prototype**
  - **Also performed flight design validation tasks and crew evaluation**
  - **Result: "Nanosatellite" free-flyer integrated into the approximate form, fit, and function of a miniaturized flight configuration**

Mini AERCam Free Flyer Capabilities

Sprint:
- 6-DOF manual control
- Automatic attitude hold (inertial)
- Analog video



Mini AERCam:
- 6-DOF manual control
- Automatic attitude hold
- Commanded attitude maneuvers
- Automatic position hold (relative)
- Commanded translational maneuvers
- Automatic surface scans
- Situational awareness (God's Eye View)
- Digital video
- Rechargeable battery
- Rechargeable propulsion

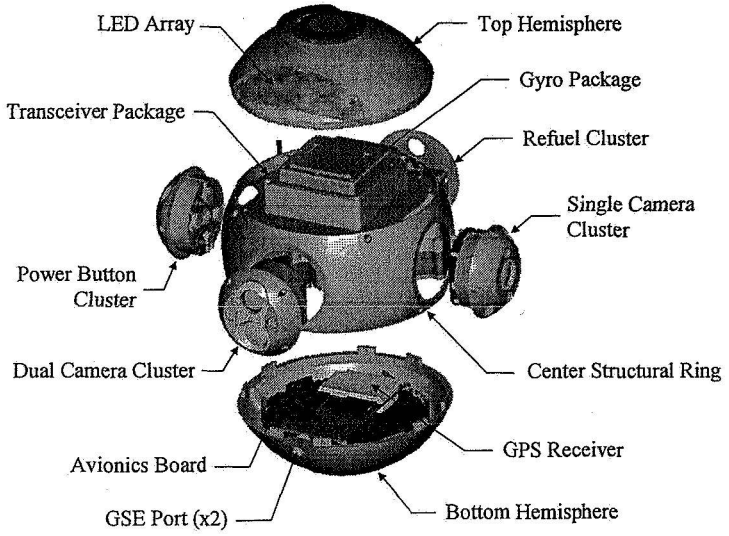
Mini AERCam Navigation Sensors

For Navigation, Sprint Had:
- Quartz rate sensors

Mini AERCam Has:

- Draper MEMS gyros
  - Smaller, lower power
- Precise Relative GPS
  - No Free Flyer pointing constraints
  - No lighting constraints
  - Does not require visual identification
  - Sub-meter accuracy
- AutoTRAC Computer Vision System (ACVS) for precise docking navigation
  - Uses retro-reflectors on docking target
  - Has space-flight heritage
  - Is tightly integrated with video system
  - Utilizes small retro-reflectors at inspection sites on spacecraft to provide autonomous navigation

Mini AERCam Free Flyer Hardware (Exploded View)



Mini AERCam Free Flyer Technologies (1 of 2)

PROPULSION

- Rechargeable pressurized xenon gas propulsion
  - 6 DOF thrusting capability (12 thruster configuration)
  - Compatible with nitrogen for ground operations

POWER

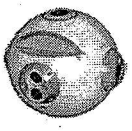
- Rechargeable batteries (Li-Ion chemistry)

VIDEO

- CMOS color cameras ("Camera on a chip")

ILLUMINATION

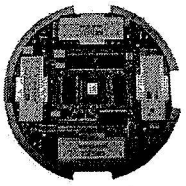
- Solid state illumination (LEDs)



Mini AERCam
Free Flyer Technologies (2 of 2)

AVIONICS

- PowerPC 740/750 based design
- FPGA-centric architecture



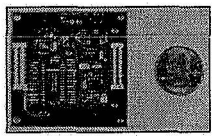
Avionics Processor Board

COMMUNICATIONS

- Digital transceiver for video, commands, and telemetry
- Micro-patch antennas for communications and GPS navigation

GN&C

- MEMS angular rate gyros for propagated relative attitude
- Relative navigation via GPS mini-receiver



MEMS Rate Gyros

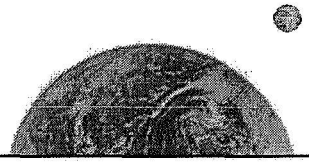
- Pilot aids: Automatic attitude hold, LVLH hold, attitude maneuvers, translation hold, point-to-point guidance

Flight-Oriented
Design Validation Activities (1 of 2)

- Thermal vacuum testing completed at JSC
  - Vehicle functioned for the duration of a 36 hour test (three representative orbital temperatures)
  - All measured component temperatures were within limits
- Radiation testing performed at University of Indiana
  - Validated use of Virtex-II Series FPGA for "hard core" avionics design
- Wireless communication link range test performed at JSC
  - Full bandwidth link with commands, telemetry and video successful at 300ft with single free flyer antenna turned 180 degrees from base station antenna

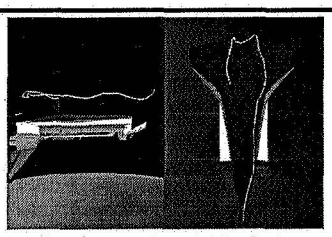
Flight-Oriented Design Validation Activities (2 of 2)

- Lighting lab test conducted
- Preliminary analyses performed for a Shuttle mission
  - Shuttle communications coverage
  - Shuttle GPS navigation coverage
  - Shuttle thermal environment analysis
- Crew evaluation
  - Nancy Currie and the Astronaut Office made significant recommendations for improving displays during crew evaluation preparations
  - All tasks completed successfully with no significant problems identified

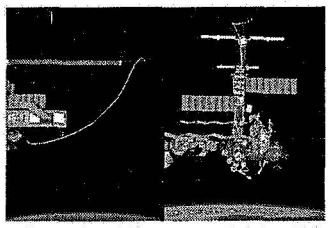


Mini AERCam Crew Evaluation

- Tests conducted over six weeks in September-October 2003
- 7 Crew Test Participants
  - Tony Antonelli
  - Drew Feustel
  - Scott Parazynski
  - Steve Lindsey *(piloted Sprint on STS-87)*
  - Steve Swanson
  - Koichi Wakata
  - George Zamka
- Seven test cases
  - 3 Shuttle
  - 3 ISS
  - 1 docking
- Crew evaluated handling qualities and situational awareness; providing favorable real-time comments



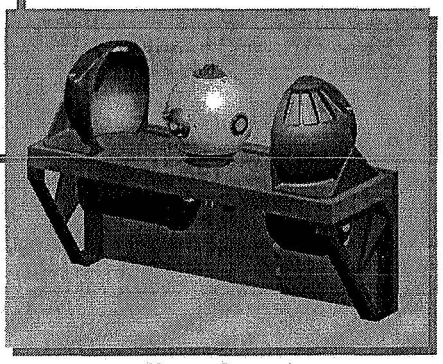
Test Case 2: Scan Orbiter Surface Scan/inspect Orbiter landing gear doors, external tank doors, and aileron hinge.



Test Case 4: Traverse to Point on ISS Starting out at the ISS airlock, fly to the tip of the starboard solar array, then hold position.

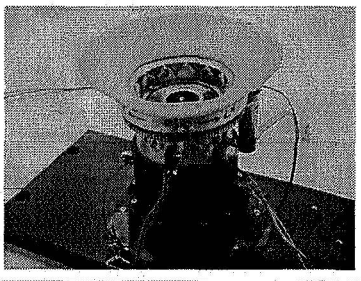
Additional Development for Shuttle Flight Testing

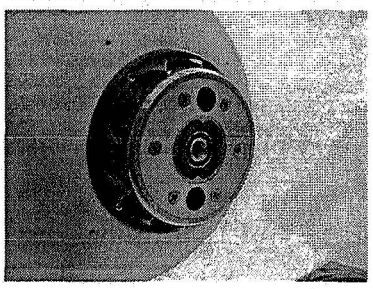
- Flight system enabling design and analyses
- Evaluation of Shuttle integration options
- Design for integration of LADAR
- Hangar design
- Magnetic docking prototype

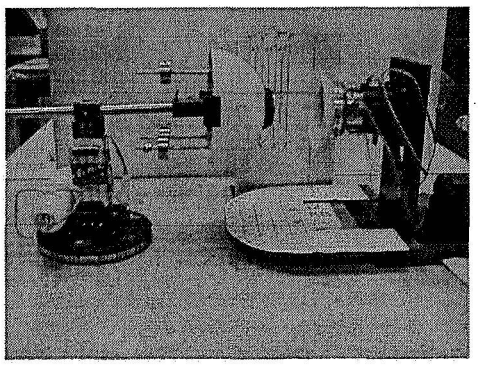


Hangar Concept

Magnetic Docking Prototype Hardware

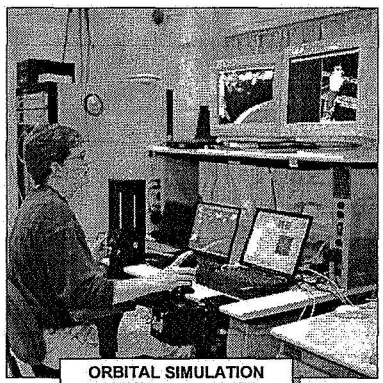






Mini AERCam Functional Testing

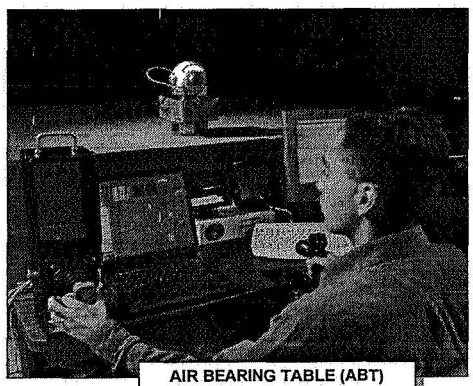
Principal Test Facilities



ORBITAL SIMULATION TEST FACILITY (OSTF)

"SAIL-like" hardware in the loop test facility, including avionics, flight software, communications, and GPS.

Both tele-operated and automatic functions.

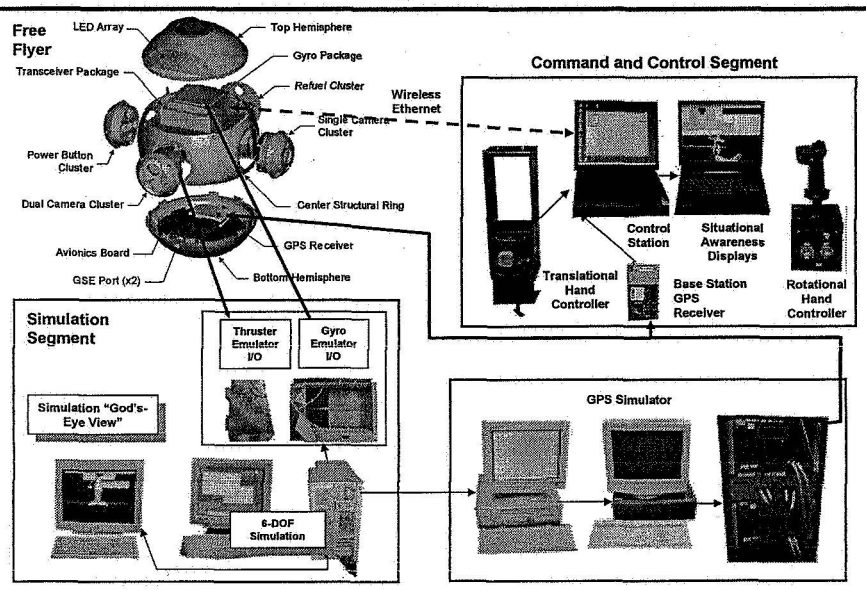


AIR BEARING TABLE (ABT) TEST FACILITY

Live air-bearing table demonstration includes avionics, flight software, communications, video, MEMS gyros, batteries, and propulsion.

Both tele-operated and automatic functions.

Orbital Simulation Test Facility Configuration



NASA Applications

AERCam is Cross-Cutting for NASA

ISS Program
- EVA/EVR viewing
- Contingency inspection
- Routine inspection

Exploration Missions
- Contingency inspection
- In-Space Assembly Viewing
- Orthogonal view of Rendezvous and Docking
- Inspection of descent vehicle thermal protection system prior to entry and landing

- Small free flyer
- Teleoperated, autonomous capabilities
- Video and still image transmission
- Situational awareness information to crew

H&RT Technology
- Free flying technology demonstrator
- Test platform for autonomy software algorithms
- Test platform for crew-autonomy interaction

Shuttle
- TPS inspection